# Documentation of Geographic Area Definitions in Support of Pacific Registers of Marine Species

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by

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## ABSTRACT

Finney, J.L., Surry, A.M., Gillespie, G.E., and Barton, L.L. 2014. Documentation of geographic area definitions in support of Pacific Region Registers of Marine Species. Can. Tech. Rep. Fish. Aquat. Sci. 3086: vii + 28 p.

In support of aquatic biodiversity research, conservation and sustainable management initiatives, Fisheries & Oceans Canada (DFO) Pacific Region is developing a regional Register of Marine Species (RMS). An RMS is comprised of two parts: a definitive list of species and a geographic area within which the listed species are found. The purpose of this paper is to provide a brief summary of some of the major geographic area classification systems used globally and regionally and make recommendations on which systems should be utilized in the Pacific Region RMS. We discuss rational for inclusion of selected geographic area classification systems in this review and define criteria against which the selected systems are measured.

## RESUME

Finney, J.L., Surry, A.M., Gillespie, G.E., et Barton, L.L. 2014. Documentation de définitions de zones géographiques à l'appui des Registres des espèces marines - Région du Pacifique. Rapp. tech. can. sci. halieut. aquat. 3086 : vii + 28 p.

À l'appui des initiatives de recherche, de conservation et de gestion durable de la biodiversité aquatique, la Région du Pacifique de Pêches et Océans Canada (MPO) élabore actuellement un Registre des espèces marines (REM). Un REM comprend deux parties : une liste définitive des espèces et une zone géographique dans laquelle se trouve l'espèce recensée. Cet ouvrage a pour objet de présenter un sommaire de certains des principaux systèmes de classification des zones géographiques utilisées partout dans le monde et dans les régions et de formuler des recommandations sur les systèmes qui devraient servir au REM de la Région du Pacifique. Nous discutons de la justification d'inclure certains systèmes de classification de zones géographiques dans ce document et définissons des critères en fonction desquels les systèmes choisis sont évalués.

# INTRODUCTION

Reliable data on species presence in given areas are needed to support ecosystem based management (EBM). A Register of Marine Species (RMS) is a definitive list of species that are reported in a given geographic area (DFO 2009a, Kennedy and Bajona 2009). The RMS can be used by scientists, managers and other stakeholders to support aquatic biodiversity research, as well as conservation and sustainable management initiatives.

There are many RMS in existence each focusing on a particular geographical area or a specific taxonomic group. For example, on the global scale, there is the World Register of Marine Species (WoRMS; http://www.marinespecies.org), while on a national scale, there is the Canadian Register of Marine Species (CaRMS; http://www.marinespecies.org/carms). These RMS provide a standardized taxonomic reference for marine species within their areas of focus. The CaRMS database is structured to feed into the larger WoRMS database, and provides an authoritative reference list of species occurring in areas of interest to Canadian scientists.

Both WoRMS and CaRMS use standardized geographic names to describe the distribution of species. All of the names used to describe the distribution of species are taken from the Vlaams Instituut voor de Zee Marine (VLIMAR) gazetteer (M. Kennedy, Fisheries and Oceans Canada, pers. comm.). Locations listed in the VLIMAR gazetteer can either describe specific geographic or oceanographic features (such as a bay or seamount) or can use alternate classification systems that describe larger regions, such as, political classification systems (e.g., Exclusive Economic Zones), management systems (e.g. Food and Agriculture Organization fishing areas), or biogeographic classification systems. Biogeographic classification systems divide geographic areas into smaller units on the basis of the distribution of taxa, and/or other ecological processes and features (e.g., currents, temperature, salinity, depth).

Fisheries and Oceans Canada (DFO) Pacific Region is developing a regional RMS. This RMS will contain information on species found within the Canadian Pacific and surrounding waters and will inform CaRMS. A step in developing this RMS is determining how to describe the spatial distribution of species.

In 2009 DFO held a national science advisory workshop to develop a framework and principles for the biogeographic classification of Canadian marine areas (DFO 2009b, O'Boyle 2010). The workshop generated a general overview and synthesis of several biogeographic classification systems, provided a list of six guiding principles and a general framework for a biogeographic classification of Canadian marine areas. It also described the accepted major biogeographic units in Canadian waters (see DFO Biogeographic Zones below).

## Selection of Geographic Classification Systems

Selection of which biogeographic classification systems to consider in this paper was based on:

1) Their inclusion in previous reviews by DFO (2009b) and O'Boyle (2010);
2) Their presence in the VLIMAR gazetteer; and
3) Their relevance to the Pacific Region of Canada.

This basis of selection meant that some systems reviewed in the two aforementioned documents were excluded, while others not reviewed were included in the current paper. For example, the Global Open Ocean and Deep Seabed Biogeographic Classification (GOODS; UNESCO 2009) system was reviewed in DFO (2009b) and O'Boyle (2010), but was not relevant to the current paper as it focuses more on the open oceans. Conversely, the International Hydrographic Organization (IHO) classification system was not reviewed in the earlier papers, but is included here as it is used in the VLIMAR gazetteer.

The purpose of this paper is to provide a brief summary of some of the major geographic area classification systems used globally and regionally and make recommendations on which system or systems should be utilized in the Pacific Region RMS. The current paper will not repeat the work done in DFO (2009b) and O'Boyle (2010), but instead will provide brief summaries of many of the biogeographic classification systems they reviewed, as well as two not included in those syntheses.

## Criteria

The geographic area classification system(s) used in the Pacific Region's RMS should include geographic area classification systems that:

1) Are described in VLIMAR (for continuity with the WoRMS and CaRMS databases);
2) Are scalable (from ocean basin to local) so that multiple spatial scales can be considered depending on what is appropriate; and
3) Extend beyond national boundaries.

# OVERVIEW OF GEOGRAPHIC AREA CLASSIFICATION SYSTEMS CONSIDERED

## BIOGEOGRAPHIC CLASSIFICATION SYSTEMS

### *Large Marine Ecosystems (LME)*

Large Marine Ecosystems of the World (LME) is a global system of biogeographic ecoregions covering vast areas (> 200,000 $km^2$)(Sherman and Alexander 1986). The LME ecoregions are not subdivided, and are differentiated by four criteria:

1) Bathymetry (bottom depth);
2) Hydrography (temperature, salinity, Sigma T, tides and currents);
3) Productivity (chlorophyll, dissolved oxygen, total zooplankton); and
4) Trophically dependent populations

There are 64 LMEs worldwide, with three on the Pacific coast of North America (Figure 1):

- Gulf of Alaska
- California Current; and
- Gulf of California.

The LME biogeographic classification system is in the VLIMAR gazetteer. LME were reviewed in DFO (2009b) and O'Boyle (2010), and additional information can be found at http://www.lme.noaa.gov/. Georeferenced spatial data files of LME boundaries are available for download from the NOAA LME website:
http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=177&Itemid=75

### *Marine Ecoregions of the World (MEOW)*

Marine Ecoregions of the World (MEOW) is a biogeographic classification of the world's coasts and continental shelves, representing broad-scale patterns of species and communities in the ocean (Spalding *et al.* 2007). The MEOW project was led by The Nature Conservancy (TNC) and the World Wildlife Fund (WWF) with broad input from a working group representing key non-governmental organizations (NGOs), academic and intergovernmental conservation partners. MEOW is a hierarchical system based on taxonomic configurations, influenced by evolutionary history, patterns of dispersal, and isolation.

MEOW consists of 12 realms, 62 provinces, and 232 ecoregions. Waters off the Pacific coast of North America are part of the Temperate Northern Pacific Realm, and incorporate two provinces of interest, Cold Temperate Northeast Pacific and Warm Temperate Northeast Pacific. A number of Ecoregions are represented on the Pacific coast of North America (Figure 2), including the following:

- Aleutian Islands;
- Gulf of Alaska;
- North American Pacific Fjordland;
- Puget Trough/Georgia Basin;
- Oregon, Washington, Vancouver Coast and Shelf;
- Northern California;
- Southern California Bight;
- Magdalena Transition; and
- Cortezian.

The MEOW classification system is in the VLIMAR gazetteer and was reviewed in DFO (2009b) and O'Boyle (2010). Further details about the MEOW system, as well as a comprehensive listing of sources, are available from the websites of the World Wildlife Fund (www.worldwildlife.org/MEOW/) and the Nature Conservancy (www.nature.org/MEOW). Georeferenced spatial data files are available for download from the VLIMAR website: http://www.vliz.be/vmdcdata/vlimar/downloads.php.

***Biogeochemical Provinces of the Ocean (BGCP)***

The Biogeochemical Provinces of the Ocean (BGCP) biogeographic classification system was developed by Longhurst (2007). This system divides the ocean into water masses with similar biological (e.g., chlorophyll *a* concentration, photosynthetic parameters) and physical properties (e.g., sea surface temperature, mixed-layer depth, bathymetry). The boundaries of this classification system are not fixed and can change based on seasonal and interannual changes in physical forcing.

The BGCP classification has two spatial scales: biomes and provinces. There are four biomes in the BGCP system: the Polar Biome, the Westerlies Biome, the Trade-Winds Biome, and the Coastal Boundary Zone Biome. These biomes are further divided into 54 provinces. The Pacific coast of North America contains five provinces (Figure 3):

- Pacific Subarctic Gyres Province;
- North Pacific Polar Front Province;
- Alaska Downwelling Coastal Province;
- California Upwelling Coastal Province; and
- Central American Coastal Province.

The BGCP classification system is in the VLIMAR gazetteer (VLIZ 2009) and is reviewed in DFO (2009b) and O'Boyle (2010). Georeferenced spatial data files for the BGCP biomes and provinces can be downloaded from the VLIMAR website: http://www.vliz.be/vmdcdata/vlimar/downloads.php.

### *Marine Ecoregions of North America (MECNA)*

Marine Ecoregions of North America (MECNA) were developed by the Commission for Environmental Cooperation (CEC) (2010). It is a collaborative effort between Canada, Mexico and the United States to protect North America's environment through the North American Agreement on Environmental Cooperation (NAAEC).

MECNA are defined as marine areas within the Exclusive Economic Zones (EEZ) of the North American countries which are generally similar in terms of physiographic, oceanographic, and biological characteristics. MECNA are constructed as a spatial framework with three nested levels. The data are intended to be

- Scalable: appropriate for perspectives and interests varying from regional to continental in scope;
- Ecosystem-oriented: based on a range of connected biological, oceanographic, and physiographic characteristics; and
- Linked: related to other marine and terrestrial data sets, classification systems, and disciplines.

There are three hierarchical levels in MECNA. The largest, Level I marine ecoregions, capture ecosystem differences at the most general scale by grouping together large water masses and currents, enclosed seas, and regions of coherent sea surface temperature or ice cover (Figure 4).

Level II marine ecoregions capture the break between near-shore and oceanic areas, with the boundaries determined by large-scale features, such as the continental shelf, continental slope, major trenches, and other features (Figure 5). Level II reflects the importance of bathymetry as well as the importance of major physiographic features in determining current flows and upwelling. The 2000 m contour is an important boundary among Level II regions.

Level III marine ecoregions capture differences within the nearshore area and are based on local characteristics of the water mass, regional physiographic features, and biological community types. Level III ecoregions are defined only for the continental shelf (defined as the 200 m contour), because this is the only ocean area for which sufficient information is available for finer-scale delineation. There are 15 Level III regions in shelf waters off the Pacific coast of North America (Figure 6):

- 19.1.1 Cape/Pacific Neritic
- 19.1.2 Vizcainean Neritic
- 19.1.3 Ensenadan Neritic
- 19.2.1 Channel Islands Neritic
- 20.1.1 San Francisco Bay Estuarine Area
- 20.1.2 Montereyan Neritic
- 21.1.1 Columbia River Estuarine Area

- 21.1.2 Columbian Neritic
- 21.1.3 Strait of Juan de Fuca
- 21.1.4 Puget Sound Estuarine Area
- 21.1.5 Strait of Georgia Estuarine Area
- 22.1.1 Fjordland Estuarine Areas
- 22.1.2 Fjordland Neritic
- 22.1.3 Gulf of Alaska
- 22.1.4 Cook Inlet

MECNA ecoregions were reviewed in DFO (2009b) and O'Boyle (2010), and are described and illustrated in Commission for Environmental Cooperation (2010). MECNA ecoregions are not described in the VLIMAR gazetteer. Maps and downloadable georeferenced spatial data files are available from the CEC website at: http://www.cec.org/Page.asp?PageID=924&ContentID=1324.

***DFO Biogeographic Zones***

Biogeographic Zones or ecoregions were defined at a DFO workshop held in 2004 attended by specialists in areas used to define the ecoregions, and confirmed in 2009 (Powles *et al.* 2004, DFO 2009b). Ecoregions were defined based on the following information:

1. Geological properties (e.g., degree of enclosure, bathymetry, surficial geology);
2. Physical oceanographic properties (e.g., ice cover, freshwater influence, water temperature, water masses, currents, mixing/stratification); and
3. Biological properties (e.g., primary productivity, species distributions, population structure and assemblages/communities).

The intent of defining ecoregions was to support various integrated management initiatives designed to meet ecosystem objectives. The Canadian marine environment was divided into 17 ecoregions, four of which are in the Pacific (Figure 7):

- Northern Shelf
- Southern Shelf
- Strait of Georgia
- Offshore Pacific

DFO Biogeographic Zones were reviewed in DFO (2009b) and O'Boyle (2010), and are not described in the VLIMAR gazetteer. Georeferenced spatial data files for DFO Biogeographic Zones were obtained from Andrea White, Scientific Advisor, Environment and Biodiversity Science, Ottawa (andrea.white@dfo-mpo.gc.ca).

### *Province of British Columbia Marine Ecoregions Classification (BC MEC)*

In the early 1990s the Province of BC's Ministry of Environment Lands & Parks began to develop a system of ecosystem classification units for wildlife inventory and management purposes (Howes *et al.* 1997). The system was updated in 2001 to include additional sources of data, such as salinity, temperature, stratification, slope, and new depth information (AXYS Environmental Consulting 2001). The system is organized in a hierarchical system of ecodivisions (Figure 8), ecoprovinces (Figure 9), ecoregions (Figure 10), and ecosections (Figure 11), and is confined to waters within Canada's jurisdiction. The data are derived from LandSat mosaics, topographic, biogeoclimatic and marine ecosystem information. Marine ecosections are as follows:

- Boundary Ranges
- Coastal Gap
- Queen Charlotte Lowland
- Queen Charlotte Ranges
- Hecate Continental Shelf
- Continental Rise
- Continental Slope
- Cascadia Continental Shelf
- Western Vancouver Island
- Pacific Ranges
- Eastern Vancouver Island
- Georgia - Puget Basin
- Lower Mainland

Due to its strictly regional focus, the BC MEC was not reviewed in DFO (2009b) or O'Boyle (2010). It is not included in the VLIMAR gazetteer. Georeferenced spatial files can be downloaded from the Province of BC's Data Distribution Service https://apps.gov.bc.ca/pub/dwds/home.so.

## Geographic, Political and Fisheries Management Zones

In addition to biogeographic classification systems, one geographic classification system, one political boundary and one international fisheries management system were considered.

### *International Hydrographic Organization Sea Areas*

In 1953 the International Hydrographic Organization published a report on the limits of oceans and seas (IHO 1953). The IHO Sea Areas are based on bathymetry and geography. The intent of the IHO Sea Areas is to insure that hydrographic publications are referring to the same area when they make references to seas and oceans.

The IHO Sea Areas describe 101 bodies of water globally, five of which lie off the Pacific coast of North America (Figure 12):

- North Pacific Ocean;
- Bering Sea;
- Gulf of Alaska;
- The Coastal Waters of Southeast Alaska and British Columbia; and
- Gulf of California.

The IHO classification system is in the VLIMAR gazetteer (VLIZ 2005a). It was not included in the reviews by DFO (2009b) and O'Boyle (2010). A georeferenced spatial data file of the areas is available for download from the VLIMAR website: http://www.vliz.be/vmdcdata/vlimar/downloads.php.

### *Canadian Exclusive Economic Zone (EEZ)*

Exclusive Economic Zones (EEZ) were developed through the 1982 United Nations Convention on Law of the Sea (UNCLOS) and formally brought into legislation in the Canadian *Oceans Act* in 1997 (DFO 2010). For this application the Canadian Pacific EEZ (Figure 13) includes four of six maritime zones defined in the *Oceans Act*:

- Internal Waters – waters landward of a Canada's jurisdictional coastline;
- Territorial Sea – 0-12 nautical miles (nm) offshore;
- Contiguous Zone – 12-24 nm offshore; and
- Exclusive Economic Zone – 12-200 nm offshore.

The Canadian Pacific EEZ is further sub-divisible, both by the legislated maritime zones outlined above, and various combinations of fishery management areas (*e.g.*, Pacific Fishery Management Areas (PFMAs), species- or fishery-specific management areas). These divisions were not judged to be informative in national and international applications, and will not be considered further.

The EEZ is the seaward boundary for some international classification systems (e.g., MEOW and MECNA) and the outer boundary for national and provincial classification systems (e.g., DFO Bioregions and BC MEC). EEZs were not considered in DFO (2009b) or O'Boyle (2010), but are included in the VLIMAR gazetteer; georeferenced spatial data files can be downloaded from the VLIMAR website http://www.vliz.be/vmdcdata/marbound/download.php.

### *FAO Fishing Areas*

The Food and Agricultural Organization of the United Nations (FAO) defined 27 major fishing areas for statistical purposes; eight are inland areas and 19 are marine areas (FAO 2002-2012). FAO Fishery Area 67 (Pacific Northeast) (Figure 14) includes

Canadian waters, however Canadian marine data holdings will include information for FAO Fishery Areas 61 (Pacific Northwest) and 77 (Pacific East Central).

The FAO Fishing Areas were not considered in DFO (2009b) or O'Boyle (2010), but are included in the VLIMAR gazetteer (VLIZ 2005b). Georeferenced spatial data files can be downloaded from the VLIMAR website at: http://www.vliz.be/vmdcdata/vlimar/downloads.php.

## HOW THE CLASSIFICATION SYSTEMS CONSIDERED MEET THE SELECTION CRITERIA

### 1. Used by VLIMAR

The Pacific Region's RMS will inform other larger RMS databases, such as WoRMS and CaRMS. Both WoRMS and CaRMS exclusively use location names found in the VLIMAR gazetteer. It therefore follows that the Pacific Region's RMS should use the same naming conventions. The LME, MEOW, BGCP, IHO, EEZ, and FAO classification systems are all defined in the VLIMAR gazetteer and used to describe the distribution of species found in the WoRMS and CaRMS databases.

### 2. Scalable

DFO (2009b) notes that "classification should be hierarchical with a nested structure based upon appropriate scales of features". As one of the objectives of the Pacific Region's RMS is to support ecosystem based management, it is essential that the system works at a range of available scales, depending on the issue at hand. Table 1 provides a summary of the classification systems examined in this paper, the areas present in BC, and whether or not the system provides classification at multiple scales. Of the nine geographic area classification systems examined in this paper, only two, MECNA and BC MEC, provide both small and large scale ecoregions.

Table 1. Summary of the geographic area classification systems, the areas contained within BC, and whether or not they are scalable.

| Classification system | Areas in British Columbia | Scalable |
|---|---|---|
| Large Marine Ecosystems (LME) | - California Current<br>- Gulf of Alaska | No |
| Marine Ecoregions of the World (MEOW) | - North America Pacific Fjordland<br>- Puget Trough / Georgia Basin<br>- Oregon / Washington / Vancouver Coast and Shelf | No |
| Biogeochemical Provinces of the Ocean (BGCP) | <u>Biome</u><br>- Coastal Boundary Zone Biome<br><u>Provinces</u><br>- Alaska Downwelling Coastal Province<br>- California Upwelling Coastal Province | No |
| Marine Ecoregions of North America (MECNA) | <u>Level I</u><br>- Columbian Pacific<br>- Alaskan/Fjordland Pacific<br><u>Level II</u><br>- Columbian Shelf<br>- Columbian Slope<br>- Columbian Plains<br>- Alaskan Fjordland Shelf<br>- North Pacific Slope<br>- North Pacific Basin<br><u>Level III</u><br>- Columbian Neritic<br>- Strait of Juan de Fuca<br>- Strait of Georgia Estuarine Area<br>- Puget Sound Estuarine Area<br>- Fjordland Neritic<br>- Fjordland Estuarine Areas | Yes |
| DFO Biogeographic Zones | - Northern Shelf<br>- Offshore Pacific<br>- Southern Shelf<br>- Strait of Georgia | No |

| Classification system | Areas in British Columbia | Scalable |
|---|---|---|
| Province of BC Marine Ecoregion Classification (BC MEC) | Ecodivisions<br>- Cool Hypermaritime and Highlands<br>- Northeastern Sub-arctic Pacific<br>Ecoprovinces<br>- Coast and Mountains<br>- Georgia Depression<br>- Northeast Pacific<br>Ecoregions<br>- Georgia-Puget Basin<br>- Hecate Continental Shelf<br>- Inner Pacific Shelf<br>- Outer Pacific Shelf<br>- Sub-arctic Pacific<br>- Transitional Pacific<br>Ecosections<br>- Boundary Ranges<br>- Cascadia Continental Shelf<br>- Coastal Gap<br>- Continental Rise<br>- Continental Slope<br>- Eastern Vancouver Island<br>- Georgia-Puget Basin<br>- Hecate Continental Shelf<br>- Lower Mainland<br>- Pacific Ranges<br>- Queen Charlotte Lowland<br>- Queen Charlotte Ranges<br>- Western Vancouver Island | Yes |
| International Hydrographic Organization (IHO) | - North Pacific Ocean<br>- Coastal Waters of Southeast Alaska and British Columbia | No |
| Canadian EEZ | Canadian EEZ Pacific | No |
| FAO Fishing Areas | FAO Fishing Area 67 (Pacific Northeast) | No |

### 3. Extends beyond Canadian national boundaries

CaRMS does not restrict its species list to those found within Canadian waters as species of interest to Canadians may lie beyond national boundaries. Historically, sharing of oceanographic data between DFO and NOAA has extended from 35° to 90° N and 40° to 180° W (Van Guelpen and Kennedy 2011). It is therefore important that the geographic area classification systems used in the Pacific Region RMS extend beyond

national borders. All of the classification systems reviewed, except for DFO biogeographic zones, EEZ and BC MEC systems extend beyond Canadian waters.

## CONCLUSIONS AND RECOMMENDATIONS

A summary of the classification systems reviewed in this paper based on selection criteria is provided in Table 2. For the purposes of the DFO Pacific Register of Marine Species the LME, MEOW, BGCP, IHO, EEZ, and FAO classification systems are recommended for consistency with WoRMS and CaRMS. In addition to being included in the VLIMAR gazetteer, the Canadian EEZ delineates boundaries for "Canadian" species, an important consideration for a national-level RMS and important legislatively in terms of the *Species At Risk Act*. FAO Fishing Areas are also commonly used in the context of fisheries data and important fishery species.

Table 2. Summary of reviewed classification systems based on selection criteria

| | **Used in VLIMAR** | **Scalable** | **Extends beyond national boundaries** |
|---|---|---|---|
| LME | **Yes** | No | **Yes** |
| MEOW | **Yes** | No | **Yes** |
| IHO | **Yes** | No | **Yes** |
| BGCP | **Yes** | No | **Yes** |
| MECNA | No | **Yes** | **Yes** |
| DFO | No | No | No |
| BC MEC | No | **Yes** | No |
| Canadian EEZ | **Yes** | No | No |
| FAO Fishing Areas | **Yes** | No | **Yes** |

The MECNA biogeographic classification system is also recommended due to its hierarchical structure containing both ocean basin and local scale divisions, which have greater relevance to Ecosystem Based Management initiatives, and because it extends beyond national borders. If the MECNA classification system is included in the Pacific Region RMS, it is recommended that attempts be made to have the boundaries of the MECNA units added to the VLIMAR gazetteer.

The BC MEC classification system has some desirable features, such as a greater number of spatial divisions and finer scale divisions that would be useful in some EBM and spatial planning work. However, because it does not cover the entire area that will be covered by the Pacific Region RMS, it is not ideal for inclusion in the Pacific Region RMS at this time.

## ACKNOWLEDGEMENTS

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## REFERENCES

AXYS Environmental Consulting Ltd. 2001. British Columbia Marine Ecological Classification Update – Final Report. Available online: ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/rpts/BCMarineEcologicalClassificationFinalReport.pdf

Commission for Environmental Cooperation. 2010. Marine Ecoregions of North America. Island Press, Washington DC. 186 p. Available online: http://www.cec.org/Page.asp?PageID=122&ContentID=2715&SiteNodeID=437&BL_ExpandID=

Fisheries and Oceans Canada (DFO). 2009a. Proceedings of the DFO Taxonomic Standards Workshop; 16-17 January 2008. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2009/021. 25 p.

DFO. 2009b. Development of a framework and principles for the biogeographic classification of Canadian marine areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/056. 17 p.

DFO. 2010. Canada's Ocean Estate. A Description of Canada's Maritime Zones. Available online: http://www.dfo-mpo.gc.ca/oceans/canadasoceans-oceansducanada/marinezones-zonesmarines-eng.htm#ex.

Food and Agricultural Organization (FAO). 2002-2012. CWP Handbook of Fishery Statistical Standards. Section H: Fisihing AREAS FOR STATISTICAL PURPOSES. CWP Data Collection. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 10 January 2002. [Cited 24 January 2012]. http://www.fao.org/fishery/cwp/handbook/H/en.

Howes, D.E., Zacharias, M.A., and Harper, J.R. 1997. British Columbia Marine Ecological Classification: Marine Ecosections and Ecounits. Available online: http://www.ilmb.gov.bc.ca/risc/pubs/coastal/marine/index.htm

International Hydrographic Organization (IHO). 1953. Limits of Oceans and Seas, Special Publication No. 23. 3rd Edition.

Kennedy, M., and. Bajona, L. 2009. A data manager's guide to marine taxonomic code lists. Can. Tech. Rep. Fish. Aquat. Sci. 2827: 23 p.

Longhurst, A. 2007. Ecological Geography of the Sea. 2nd Edition. Elsevier Science Publishers. New York. 542 p.

O'Boyle, R. 2010. Review of selected Biogeographic Classification Systems with a relevance to the Canadian marine environment. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/066. vi + 81 p.

Powles, H., Vendette, V., Siron, R., and O'Boyle, B. 2004. Proceedings of the Canadian Marine Ecosystems Workshop. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2004/016. 47 p.

Sherman, K., and Alexander, L.M. [eds.]. 1986. Variability and management of large marine ecosystems. AAAS Selected Symposium 99. Westview Press Inc., Boulder, CO. 319 pp.

Spalding, M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdaña, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., Mcmanus, E., Molnar, J., Recchia, C.A., and Robertson, J. 2007. Marine ecoregions of the world: A bioregionalization of coastal and shelf areas. Bioscience 57(7): 573-583.

UNESCO. 2009. Global Open Oceans and Deep Seabed (GOODS) – biogeographic classification. Paris, UNESCO-IOC. IOC Tech. Ser. 84. 89 p.

Van Guelpen, L., and Kennedy, M.K. 2011. The history of Canadian registers of marine species 2001-2009. Can. Tech. Rep. Fish. Aquat. Sci. 2906: iv + 20 p.

Vlaams Instituut voor de Zee (VLIZ). 2005a. IHO Sea Areas. Available online at http://www.vliz.be/vmdcdata/vlimar/downloads.php. Consulted on 2012-01-25.

VLIZ 2005b. FAO Fishing Areas Geodatabase. Available online at http://www.vliz.be/vmdcdata/vlimar/downloads.php. Consulted on 2012-01-25.

VLIZ 2009. Longhurst Biogeographical Provinces. Available online at http://www.vliz.be/vmdcdata/vlimar/downloads.php. Consulted on 2012-01-25.

# FIGURES

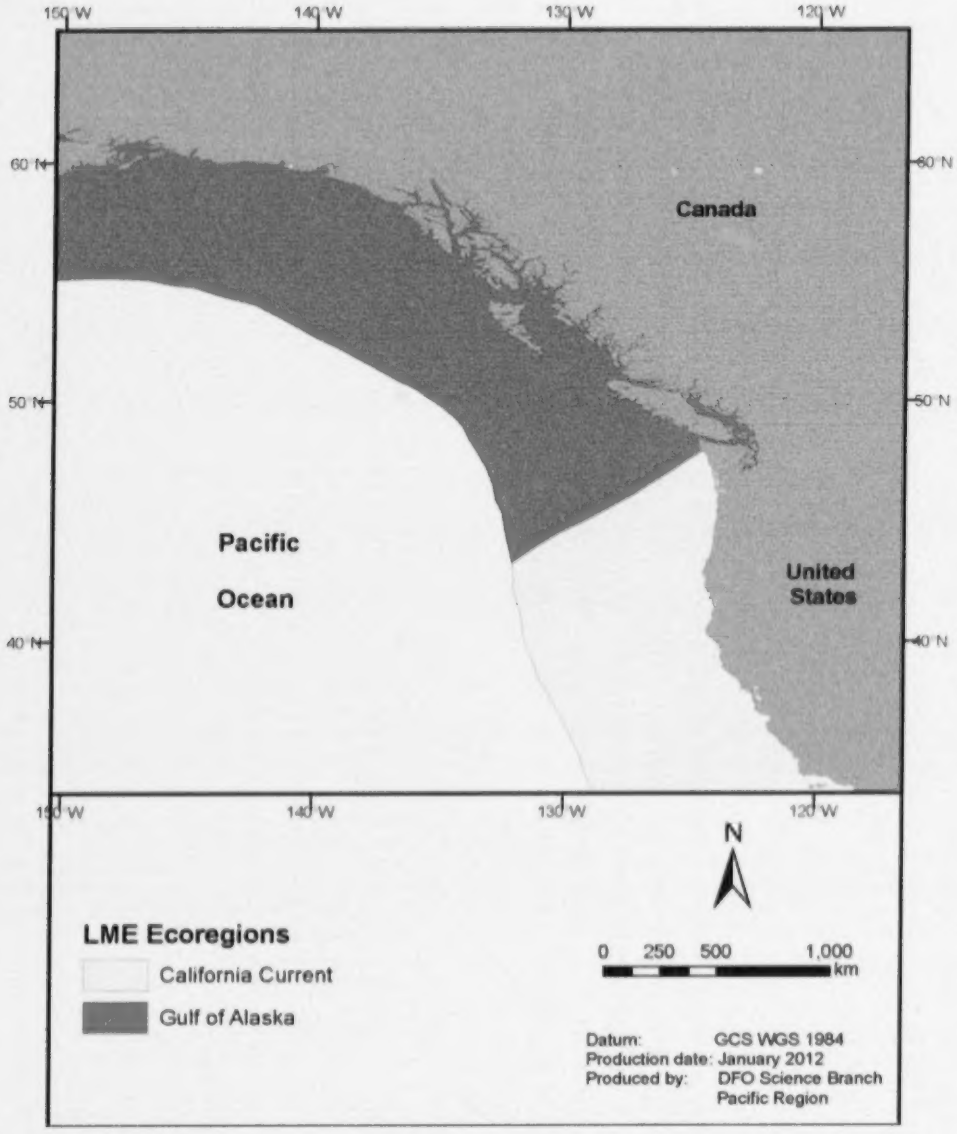


Figure 1. Large Marine Ecosystems (LME) in Pacific North America.

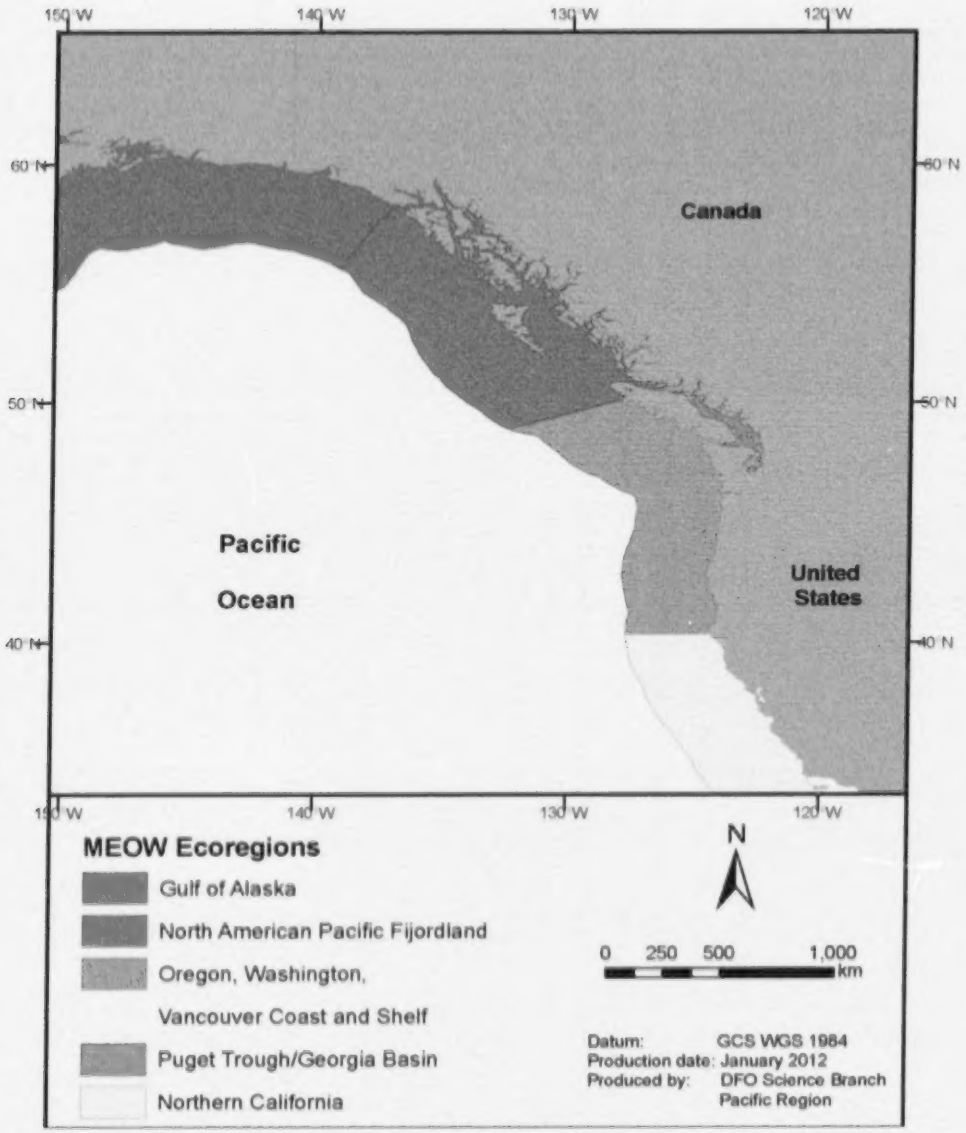


Figure 2. Marine Ecoregions of the World (MEOW) in Pacific North America.

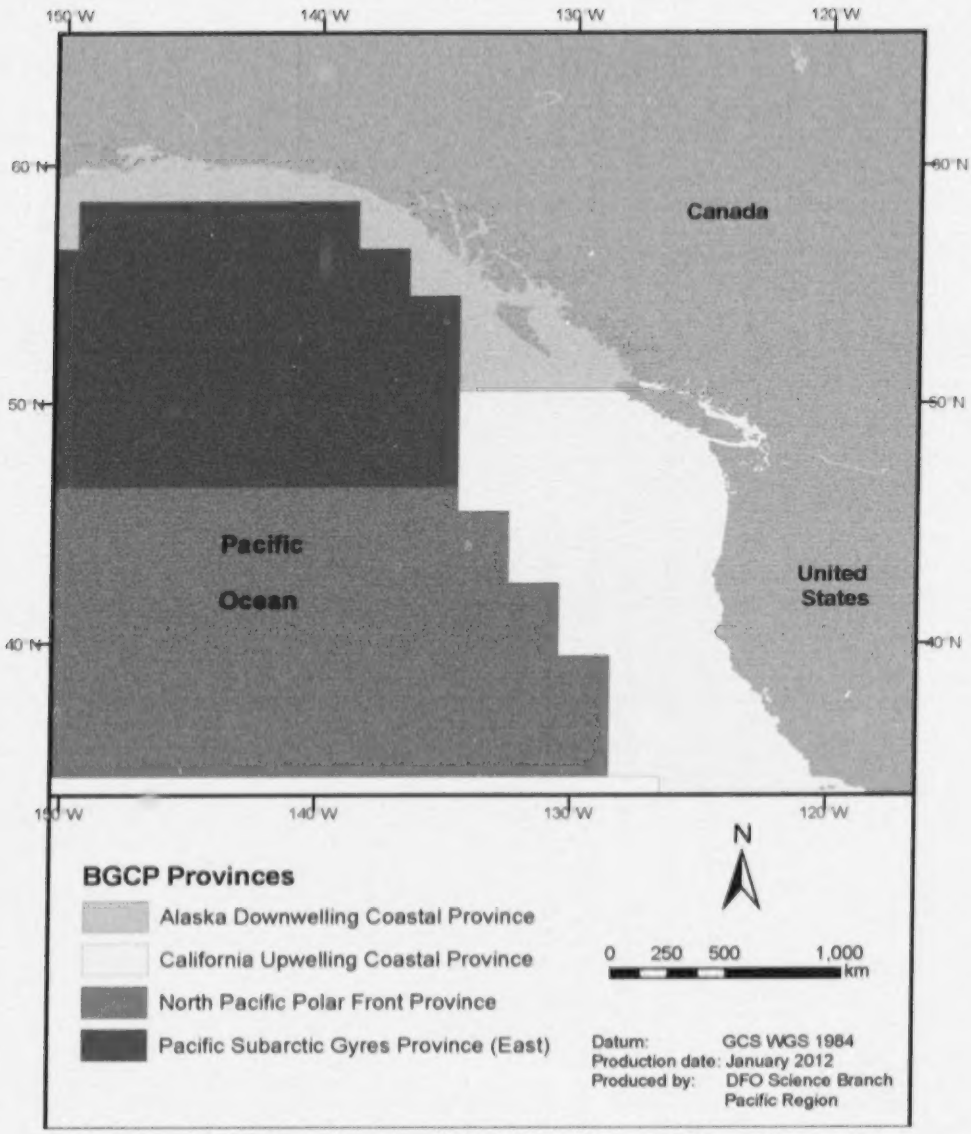


Figure 3. Biogeochemical Provinces (BGCP) in Pacific North America.

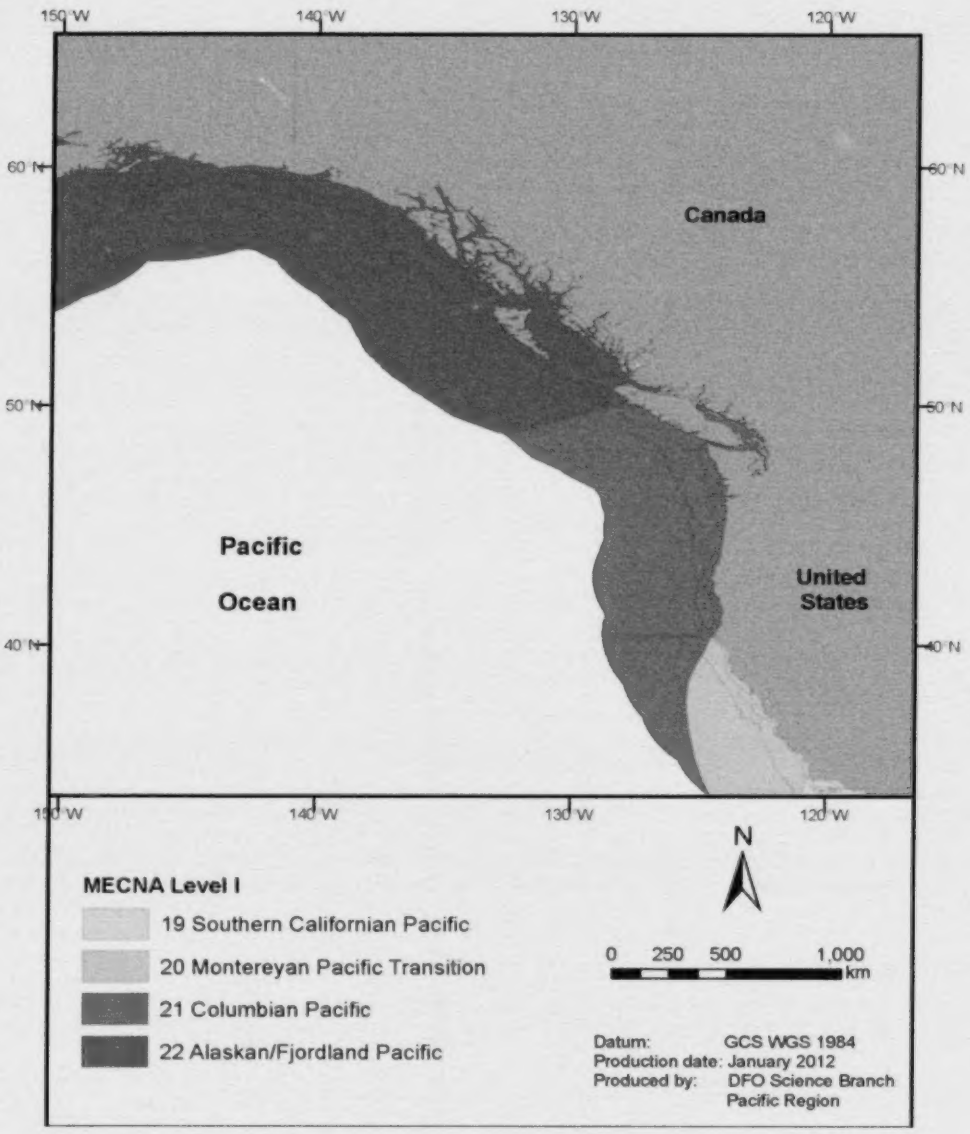


Figure 4. Marine Ecoregions of North America (MECNA) Level I ecoregions in Pacific North America.

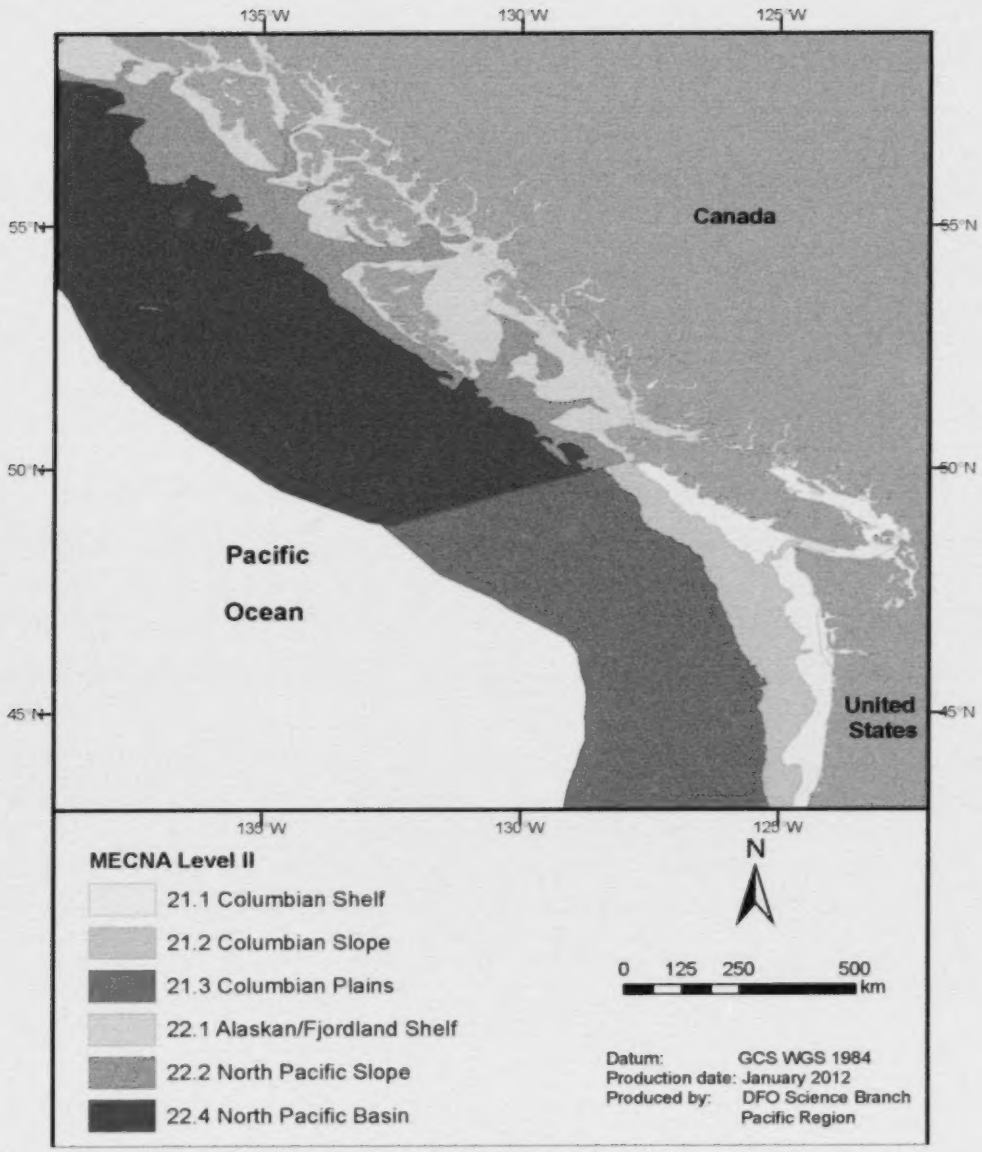


Figure 5. Marine Ecoregions of North America (MECNA) Level II ecoregions in Pacific Canada.

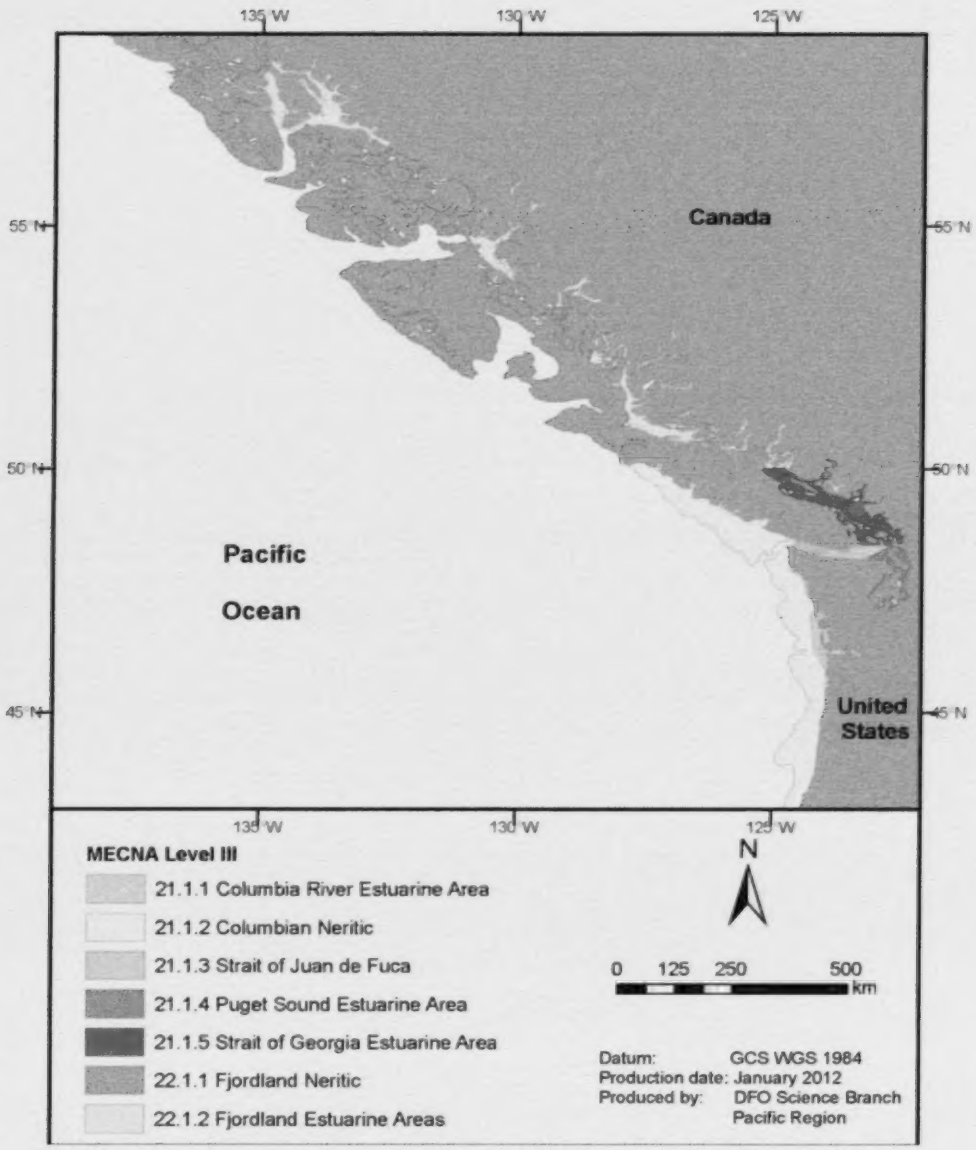


Figure 6. Marine Ecoregions of North America (MECNA) Level III ecoregions in Pacific Canada.

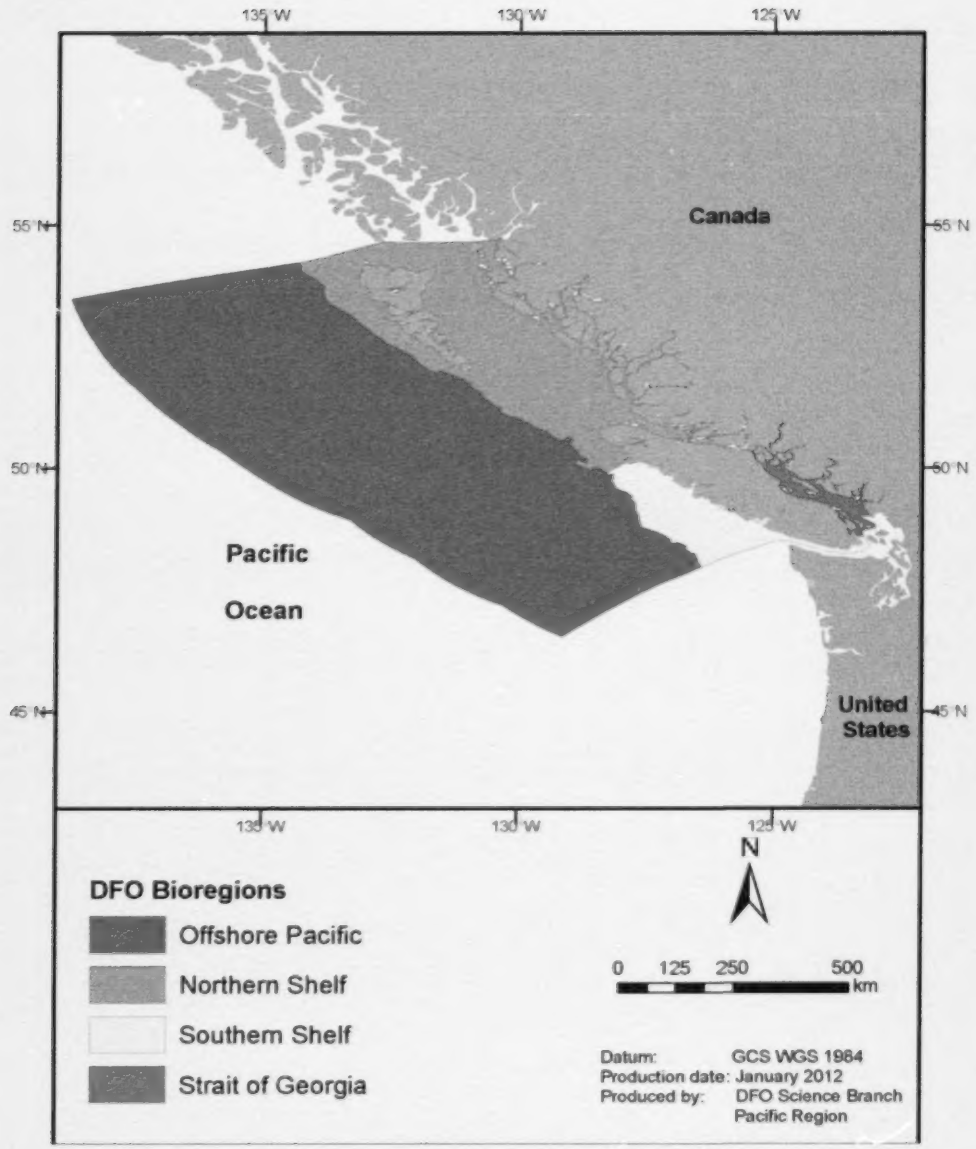


Figure 7. Fisheries and Oceans Canada (DFO) bioregions in Pacific Canada.

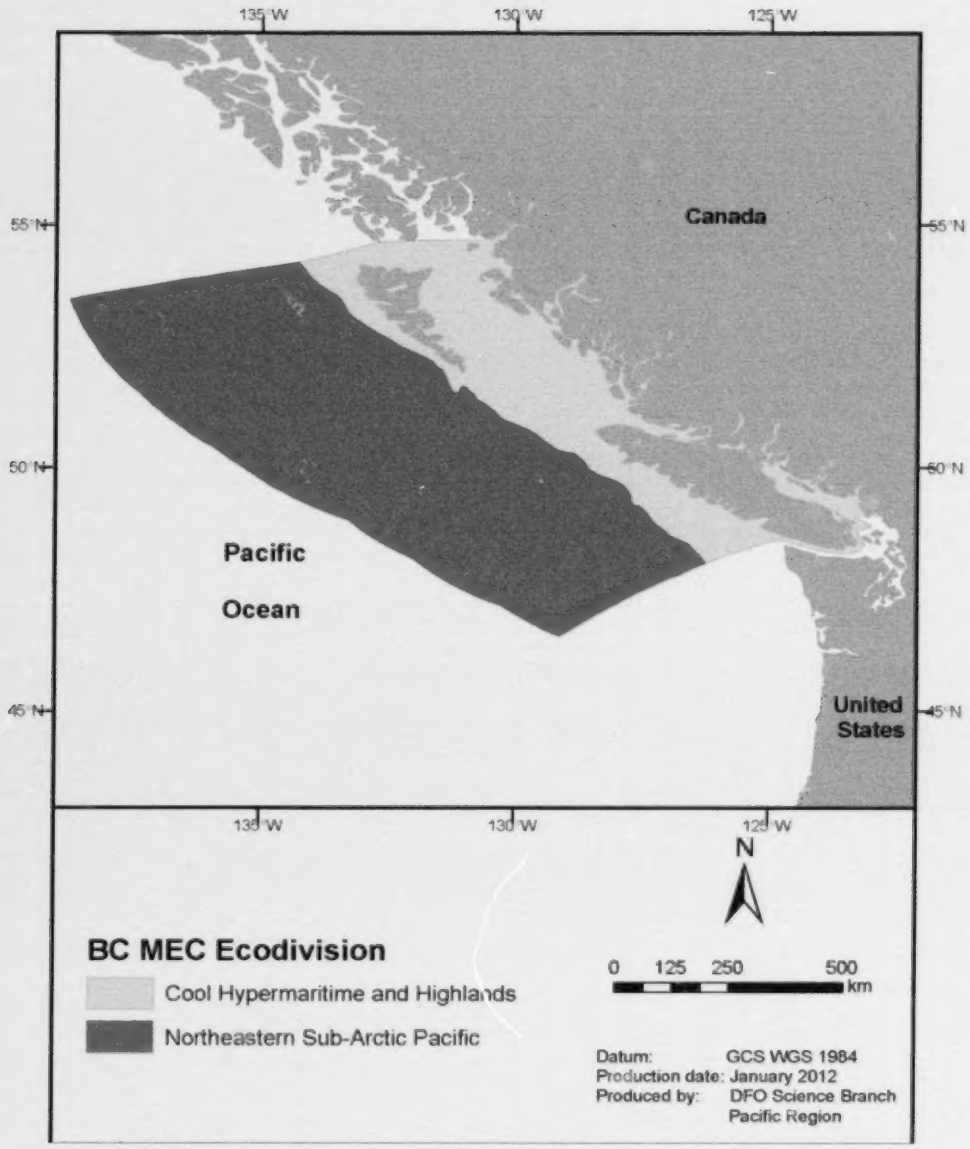


Figure 8. The Province of BC's Marine Ecoregion Classification (BC MEC) largest classification unit, ecodivisions.

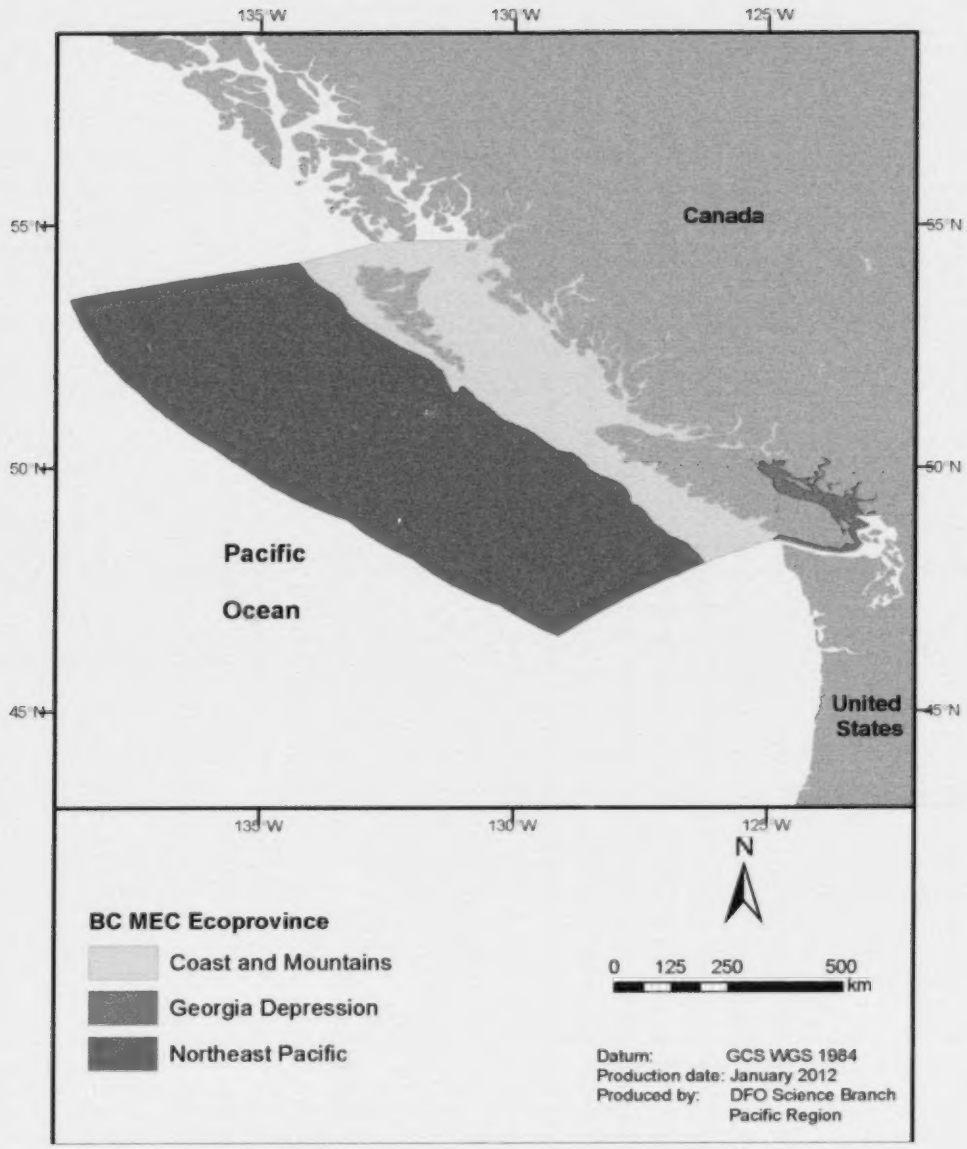


Figure 9. The Province of BC's Marine Ecoregion Classification (BC MEC) ecoprovinces.

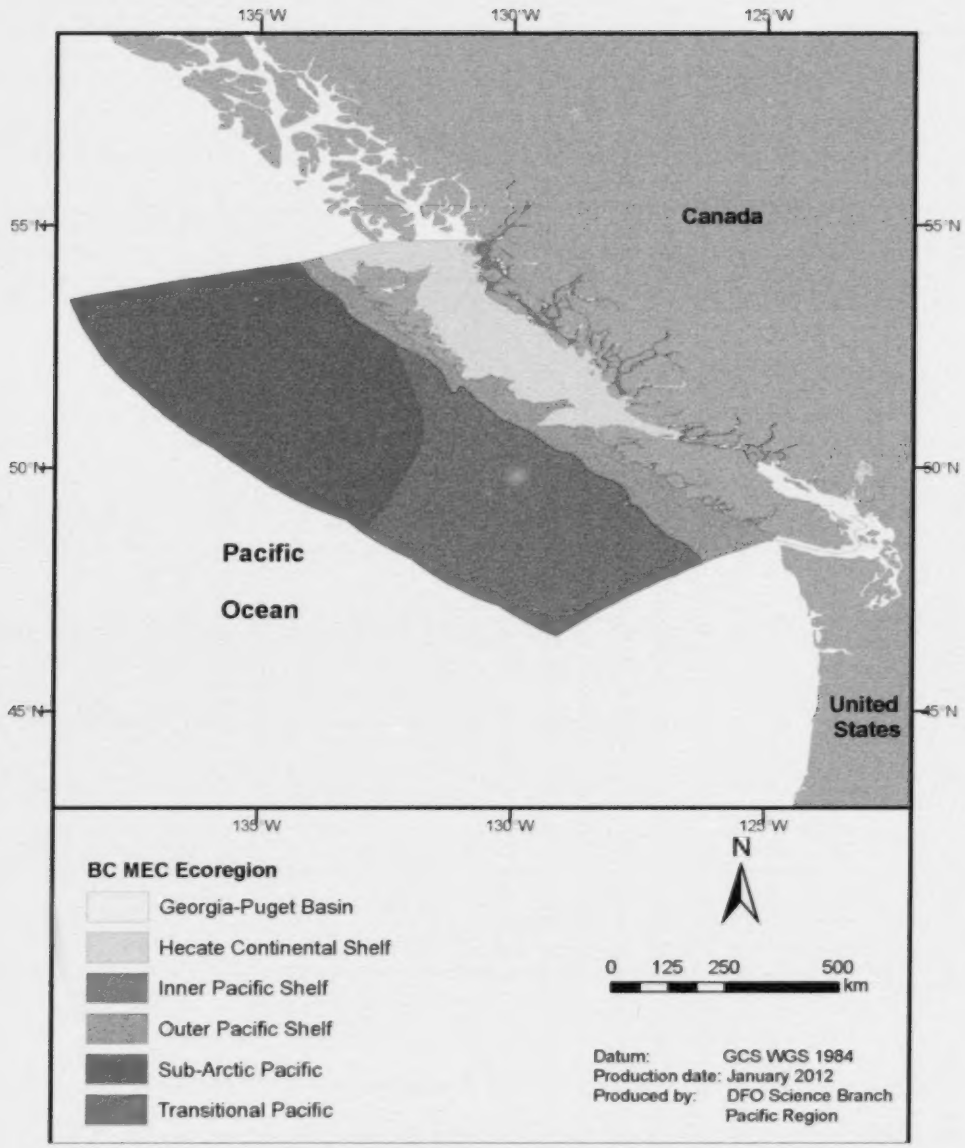


Figure 10. The Province of BC's Marine Ecoregion Classification (BC MEC) ecoregions.

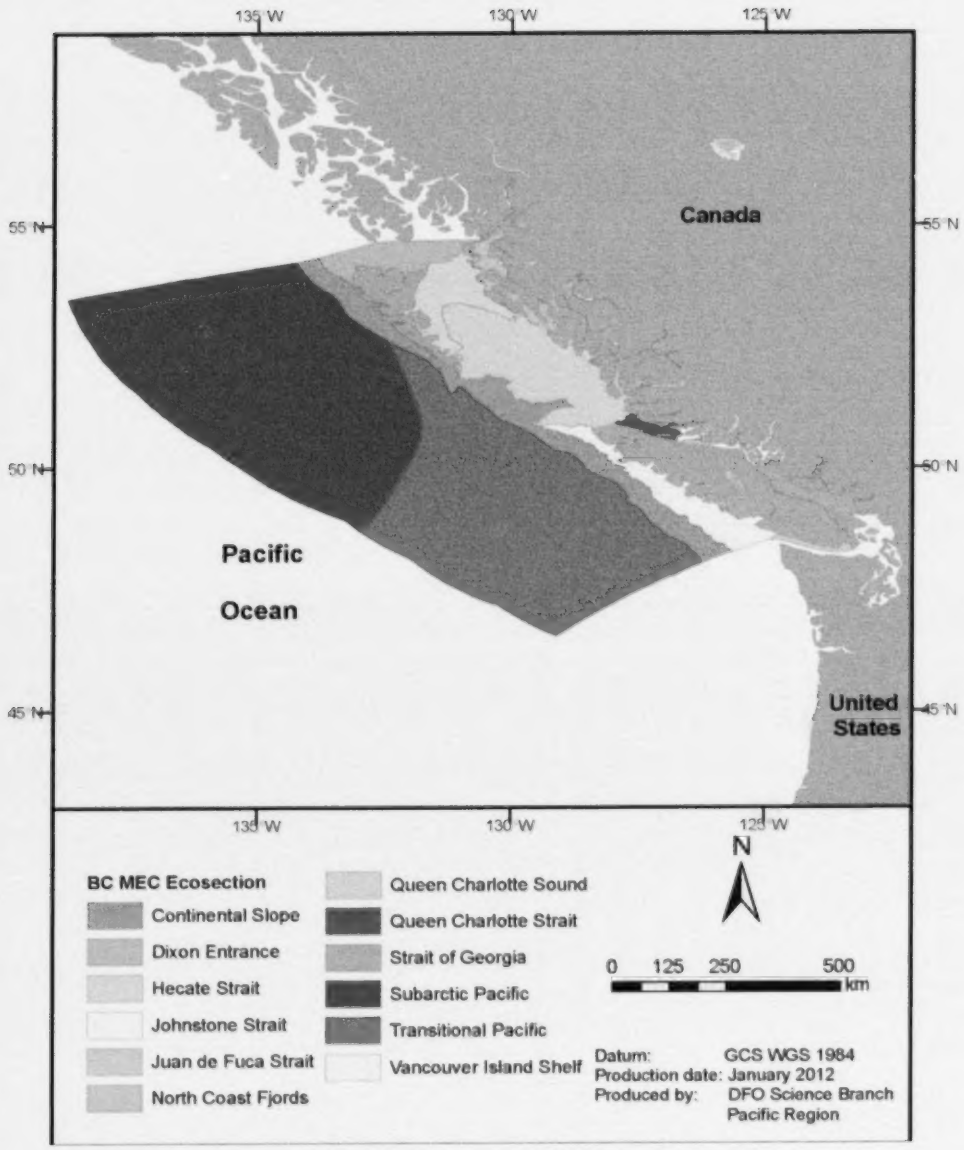


Figure 11. The Province of BC's Marine Ecoregion Classification (BC MEC) smallest classification units, ecosections.

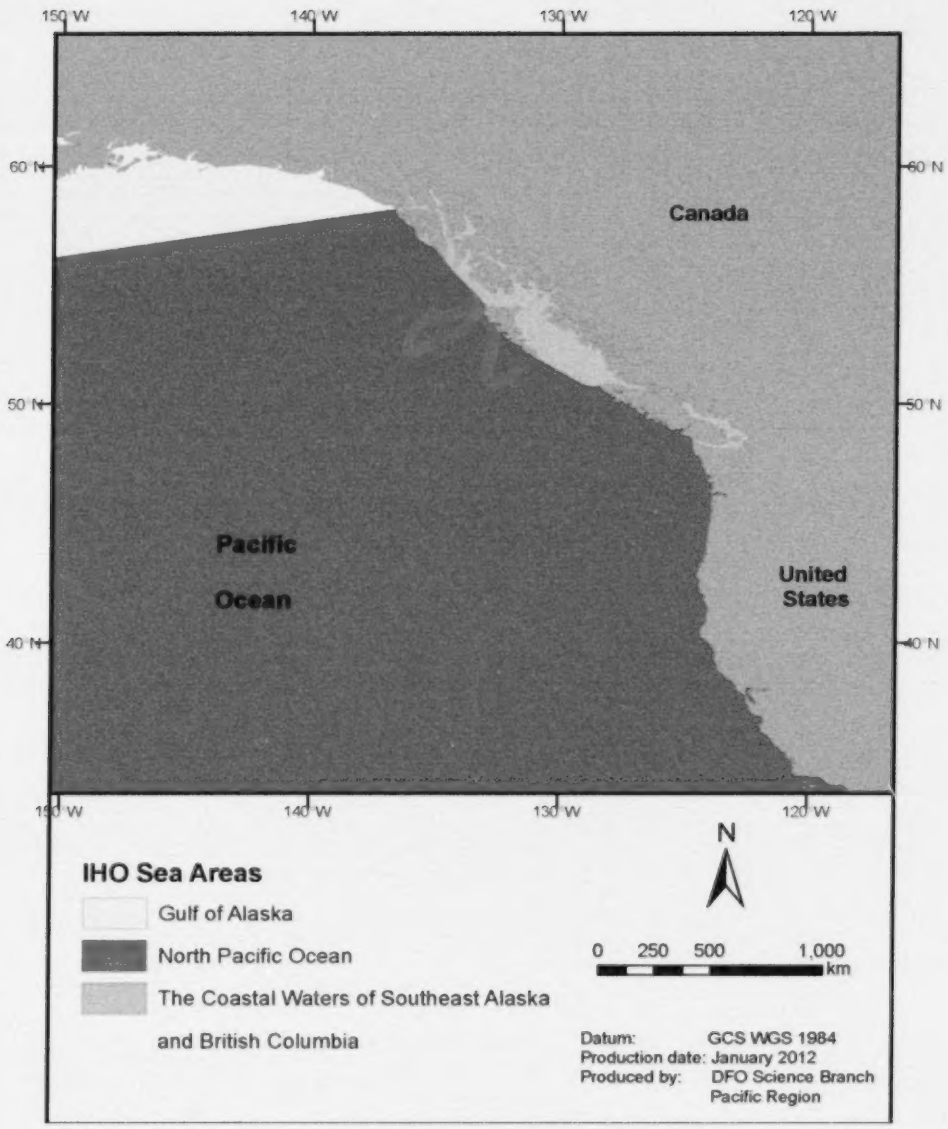


Figure 12. International Hydrographic Organization (IHO) Sea Areas in Pacific North America.

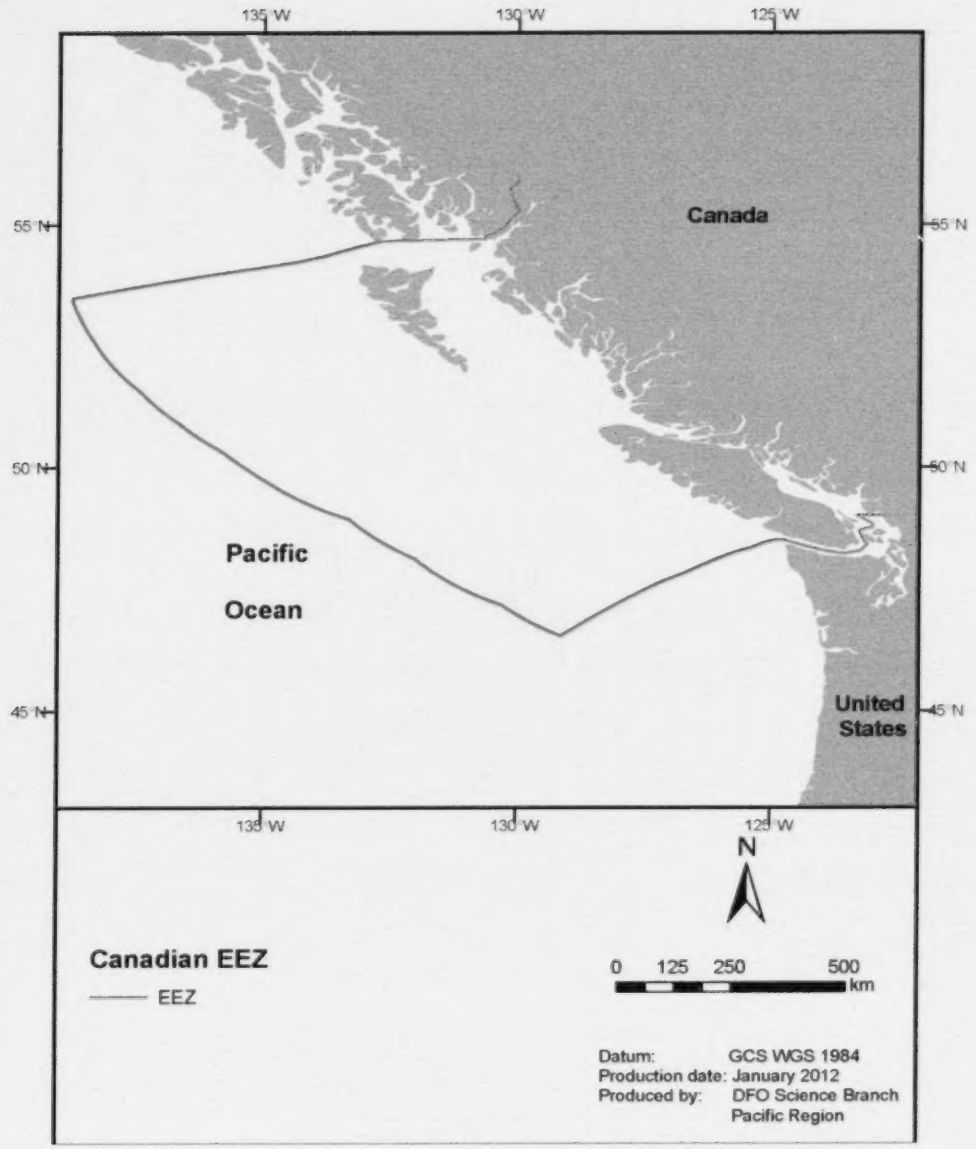


Figure 13. Canadian Exclusive Economic Zone for the Pacific Region (EEZ Pacific).

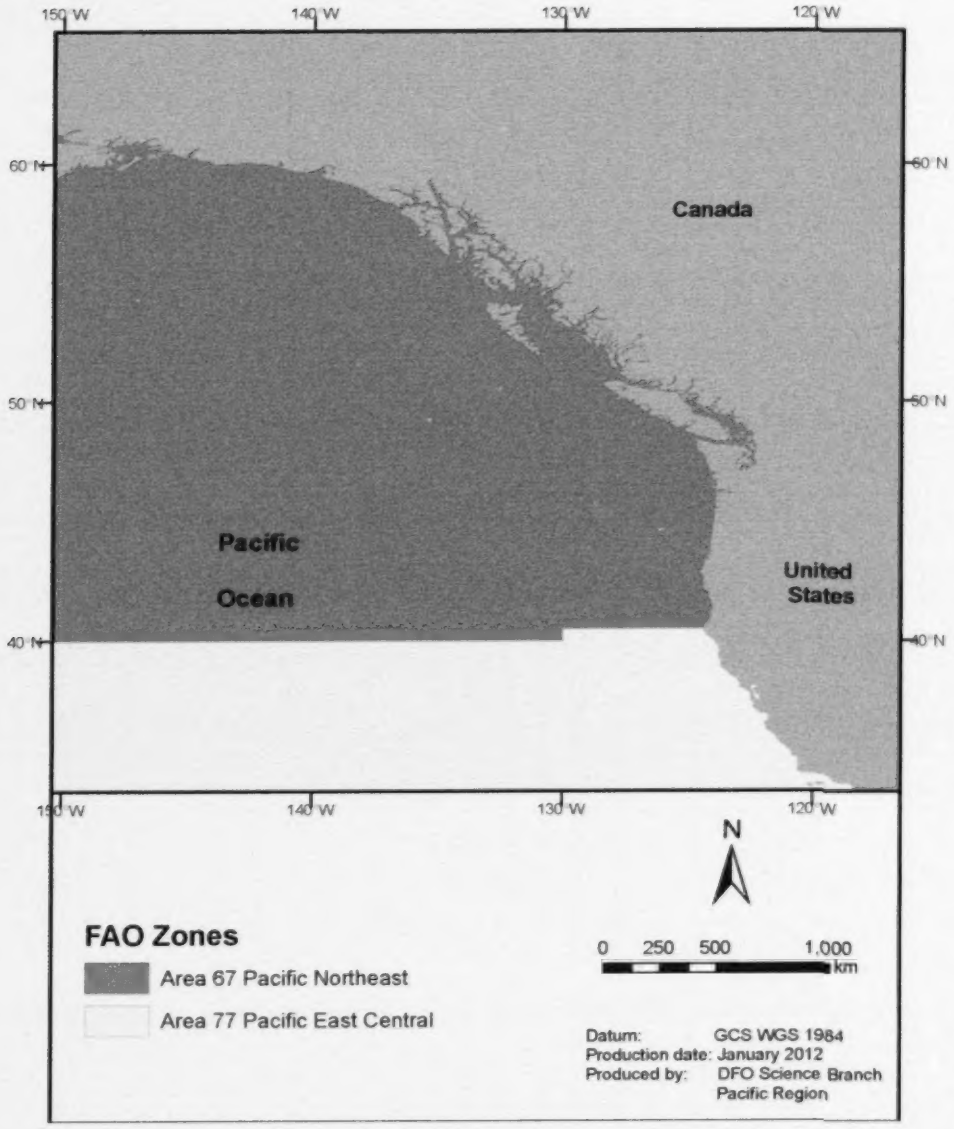


Figure 14. FAO Fishing Areas 67 (Pacific Northeast) and 77 (Pacific East Central).